Professional Development Leave Report

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Summary Statement

I have successfully accomplished the goals stated in my PDA assignment, which included the completion of a book on brain dynamics with my co-author (W.J. Freeman, UC Berkeley). An additional goal I accomplished was the development of a mathematical framework for strategy change in cognition as part of the collaboration with my German collaborator (F. Ohl, Leibniz Institute of Neurobiology, Magdeburg, Germany). Here I provide details of these achievements.

PDA Accomplishments

1. **Writing a monograph on hierarchical mathematical models of spatio-temporal dynamics of brain functions.**

   As a result of my stay at UC Berkeley with Dr. Walter Freeman in Fall 2014, we have finalized the manuscript of our book, and in January 2015 it has been submitted to the publisher, Springer Verlag, Heidelberg, Germany. After adding some commentaries by leading experts in the field, the book is published as follows:

   - R. Kozma and W.J. Freeman, *"Cognitive Phase Transitions in the Cerebral Cortex - Enhancing the Neuron Doctrine by Modeling Neural Fields, "*Springer Verlag, Heidelberg (2015).

   Springer advertises the book as follows:
   This intriguing book was born out of the many discussions the authors had in the past 10 years about the role of scale-free structure and dynamics in producing intelligent behavior in brains. The microscopic dynamics of neural networks is well described by the prevailing paradigm based in a narrow interpretation of the neuron doctrine. This book broadens the doctrine by incorporating the dynamics of neural fields, as first revealed by modeling with differential equations (K-sets). The book broadens that approach by application of random graph theory (neuropercolation). The book concludes with diverse commentaries that exemplify the wide range of mathematical/conceptual approaches to neural fields. This book is intended for researchers, postdocs, and graduate students, who see the limitations of network

theory and seek a beachhead from which to embark on mesoscopic and macroscopic neurodynamics.

2. Development of the mathematical framework of large-scale network dynamics for strategy change in cognitive biological and technical systems.

- During the PDA period I have been conducting research on my NSF (DMS-13-11165) collaborative research project *"US-German Collaboration on the Computational Neuroscience of Strategy Change in Cognitive Biological and Technical Systems,"* and I visited the Lab of my Colleague Frank Ohl, Director of Neurobiology Laboratory, at the Leibniz Institute of Neurobiology, University of Magdeburg, Germany.

- The focus of my research has been to describe strategy change, i.e., the change in action selection and action planning while an overarching goal is maintained is a fundamental, which is a barely understood capability of cognitive systems in animals and humans. Sudden transitions are well documented in neurophysiological and cognitive experimental data, but the development of the underlying mathematical theory of the spatio-temporal dynamics is yet in its infancy. In recent years, I have made progress in understanding the nature and functional role of abrupt, large-scale state transitions in brains.

- During the PDA I also worked on new research results to address broader societal needs by creating the foundations for flexible and robust emergency response systems in case of natural disasters, cyber security threats, as well as optimized control of autonomous vehicles under complex operating conditions.

- Published outcomes from the research I conducted during the PDA are listed at the end of this report (1 book; 2 journal manuscripts, 3 conference papers presented, 6 invited talks).

3. Benefits to the academic and research activity at the Department and University

- The Math Department benefits from the PDA outcomes through educational activities in curriculum and program development. The new book I produced is based partly on my earlier graduate classes, and having a comprehensive textbook would significantly benefit students in the future.

- The experience I gained during my PDA period has been used in my teaching activities both at graduate and undergraduate levels. In addition to the research involvement of grad students, I also attract bright undergrad students to gai research experience.

- I promoted our applied math program and our university at my visits at a number of US and overseas universities and Labs: UC Berkeley; UC Merced; UMass Amherst; U Arizona at Tempe; Caltech Jet Propulsion Lab, Pasadena, CA; U Magdeburg, (Germany); U of Chile Santiago, and U of Antofagasta (Chile),

Publications resulted from the PDA

Book (1)

- R. Kozma and W.J. Freeman, *"Cognitive Phase Transitions in the Cerebral Cortex - Enhancing the Neuron Doctrine by Modeling Neural Fields, "*Springer Verlag, Heidelberg (2015).

Manuscripts submitted to journals (2)

- Kozma, R., Puljic, M. "Random graph theory and neuropercolation for modeling brain oscillations at criticality, " submitted to *Current Opinion in Neurobiology.*
- Freeman, W.J., Capolupo, A., Kozma, R., Campo, A.O., Vitiello "Bessel functions in mass action modeling of memories and remembrances," submitted to *Phys. Lett. A.*

Conference papers presented (3)

- Sokolov, Y., Kozma, R., "Stability of dynamic brain models in neuropercolation approximation," *Proc. IEEE Conf. Systems, Man, and Cybernetics (SMC2014),* Oct. 5-8, 2014, San Diego, USA, IEEE, pp. 2230-2233.
- Dutta, J. K., Banerjee, B., Ilin, R., & Kozma, R. (2014) "Abnormal event detection in EEG imaging-Comparing predictive and model-based approaches." In *Proc. 2014 IEEE Symposium Series SSCI2014, Computational Intelligence in Brain Computer Interfaces (CIBCI), Dec. 9-12, 2014, Orlando, USA,* pp. 10-15. IEEE.
- Davis, J.J.J., Kozma, R. (2014) "Sensitivity analysis of Hilbert transform with band-pass FIR filters for robust brain computer interfaces," in *Proc. 2014 IEEE Symposium Series SSCI2014, Computational Intelligence in Brain Computer Interfaces (CIBCI),* Dec. 9-12, 2014, Orlando, USA, pp. 16-21, IEEE.

Invited/Plenary Talks (6)

- *Invited Talk: "*Transient Spatio-Temporal Dynamics as Modus Operandi of Large-Scale Networks," *Antofagasta University,* December 18, 2014, Chile.
- *Plenary Talk: "*Transient Spatio-Temporal Dynamics as Modus Operandi of Large-Scale Networks," *Xth IEEE Latin-American Summer School on Computational Intelligence*, Dec. 16, 2014, University of Chile, Santiago, Chile.
- *Featured Talk:* "Phase Transitions in the Auditory Cortex of Gerbils During Reinforcement Learning Indicating Strategy Change," 2014 *NSF Collaborative Research on Computational Neurosciences (CRCNS) PI Meeting,* October 16-18, 2014, Tempe, AZ, USA.
- *Invited Talk: "*Transient Dynamics of the Intentional Action-Prediction Cycle - Theory, Experiments & Applications," *NASA Jet Propulsion Laboratory,* Division of Robot Autonomy, October 9, 2014, Pasadena, CA.
- *Invited Talk: "*Transient Cognitive Dynamics Modeled through Criticality in Brains," School of *Cognitive and Information Sciences, University of California at Merced,* October 21, 2014, Merced, CA.
- *Invited Talk:* "Neuropercolation Models of Cortical Neurodynamics – Interpretation of Transient Cognitive Dynamics," *University of Massachusetts at Amherst,* October 2, 2014, Amherst, MA.